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Impact of external knowledge acquisition strategies on innovation – A comparative study based on Dutch and Swiss panel data

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Abstract

There is growing evidence that firms increasingly adopt open innovation practices. In this paper we investigate the impact of two such external knowledge acquisition strategies, 'buy' and 'cooperate', on firm's product innovation performance. Taking a direct (productivity) approach, we test for complementarity effects in the simultaneous use of the two strategies, and in the intensity of their use. Our results based on large panels of Dutch and Swiss innovating firms, suggest that while both 'buy' and 'cooperate' have a positive effect on innovation, there is little statistical evidence that using them simultaneously leads to higher innovation performance. Results from the Dutch sample provide some indication, that there are positive economies of scope in doing external and cooperative R&D simultaneously conditional on doing internal R&D.

INTRODUCTION

This is a paper on the impact of external knowledge acquisition strategies on innovation performance and is mainly motivated by the observation of the necessity of the acquisition of new knowledge as a precondition for successful innovative activities of enterprises. New knowledge is generated not only inside the boundaries of a firm but also acquired from the environment. Even the largest and most technologically self-sufficient enterprises require knowledge from beyond the firm boundaries. In addition to own research and development (internal R&D) enterprises typically are engaged in the trading of knowledge on the technology market (contract or external R&D) and/or co-operate actively – formally or informally – with other firms and research institutions. For applied industrial economics it is an important task understanding how firms integrate internal knowledge and various types of externally acquired knowledge and if such activities increase firms' performance. In the last years there is an increasing interest in economic literature to analyse the influence of alternative knowledge acquisition strategies on firm performance (see, Cassiman and Veugelers 2006; Belderbos et al. 2006 for two important papers on this topic). An important motive for this research interest is the improvement of our understanding of the role of such strategies with respect to the innovation performance and the output performance of enterprises that engage in such strategies. Better insights into knowledge acquisition strategies and their impact on firm performance would allow the formulation of a knowledge-based technology policy.

We focus in the paper at hand on two knowledge acquisition strategies: external or contract R&D and R&D (innovation) co-operation. Both strategies indicate a tendency to open the innovation process ("open innovation"; see, e.g., Laursen and Salter 2006); however they are not identical with respect to the appropriability implications. When the buy strategy is used firms are obviously not interested in protecting the R&D (innovation) outcomes from competitors or keeping them secret from them. The appropriability requirements are much more severe in case of cooperative projects ("coop strategy"), in which (sharing of) property rights (is) are properly arranged, even if they cannot be as exclusive as for in-house R&D (innovation) ("make strategy"). In this sense the "buy" (contract R&D) and "coop strategy" could be used alternatively. It is then interesting, also for policy, to know, if firms use them alternatively or complementarily to benefit from the combined use of both types of external knowledge acquisition.

Why a comparative study? There are two main arguments for justifying that choice: first, comparative studies help to test the validity and robustness of theoretical notions about the relationship of different strategies of knowledge acquisition and their (combined) impact on innovation performance on a broader basis and, second, serve to investigate the relative importance or effectiveness of knowledge acquisition strategies with respect to innovativeness in different countries as basis for evidence-based policy.

Why a comparative study of the Netherlands and Switzerland? It is interesting to investigate the impact of knowledge acquisition strategies on innovation performance for two countries that show several similarities (small, open economies, technologically advanced – near the "technological frontier"; Switzerland: "innovation leader"; Netherlands: "innovation follower" according to EIS (European Innovation Scoreboard) 2008 assessment) and at the same time differences that might be relevant for the outcomes of knowledge acquisition strategies: EU membership; more active innovation policy in the Netherlands, e.g., more public support of corporate R&D (almost non-existing in Switzerland) and R&D (innovation) cooperation.

What is the originality of this study? First, the investigation of the impact of the external R&D and R&D (innovation) co-operation as well as the combined effect of these two strategies based both on qualitative and quantitative variables that measure the two strategies and separately for manufacturing and services using three cross-sections of firm data for both countries and, second, the comparison of two technologically advanced European countries with different innovation policies that might influence corporate strategies of knowledge acquisition.

Informed by the growing literature on open innovation (Chesbrough, 2003; Dahlander and Gann, 2010; Drechsler, and Natter, 2012; Fey and Birkinshaw, 2005), we expected that the more firms rely on different external knowledge sourcing modes, the better they would perform in terms of innovation. While we find some evidence that both external technology sourcing and R&D cooperation positively impact innovation in isolation, we hardly find evidence of an additional gain in performance when both are used simultaneously.

The structure of the paper is as follows: in section 2 we discuss briefly related empirical literature. Section 3 presents the model specification. Section 4 deals with the data. In section 5 we discuss the method and present the results. Finally, section 6 concludes.

2. REVIEW OF RELATED EMPIRICAL LITERATURE

We concentrate here on the line of empirical research on knowledge acquisitions strategies that emphasize the performance implications of external knowledge sourcing, particularly the possible complementarity of such strategies, i.e. the mutual strengthening with respect to economic performance. Studies in this line investigate the impact on innovation performance as well as on economic performance in the narrow sense, e.g. labour productivity.

Beneito (2006) investigated based on longitudinal data of Spanish firms mainly two hypotheses: (a) in-house R&D activities are more productive in terms of significant innovations leading to patents than contract R&D, which, in turn, is more productive than internal R&D in terms of incremental innovations (utility models); (b) the composition of total R&D investment matters. The analysis confirms both hypotheses. Thus, in-house and contract R&D show different effects on innovation performance. Contract R&D has to be combined with in-house R&D in order to contribute effectively to more significant innovations. Both together lead to economically more valuable results.

Analysing a sample of Belgian manufacturing firms Cincera et al. (2003) found that besides internal R&D co-operation with foreign partners, particularly, customers, foreign suppliers or other foreign companies seems to stimulate significantly firm productivity growth. In contrast, R&D co-operation with Belgian partners is associated with low productivity growth.

Peeters and van Pottelsberghe de la Potterie (2006) could confirm in a study with data of Belgian firms the results of Beneito (2006) (see above) regarding the higher productivity of in-house R&D with respect to patents in comparison to contract R&D. They found that the choice of a specific innovation strategy is more important than other firm or sector characteristics for explaining patent activities. Especially R&D co-operation with external partners enhances patent activities of firms. Furthermore, firms focussing on process innovation are less likely to have patents than product-oriented innovating firms.

Cassiman and Veugelers (2006) investigated based on Belgian manufacturing firm data in their pioneering work on “complementarity in innovation strategy” the main drivers for internal (“make”) and/or external (“buy”, co-operation) knowledge acquisition strategies. In addition, they analysed the impact of different knowledge strategies on product innovation performance. By applying several econometric estimation methods the authors found that there exists complementarity between the strategies “make” and “buy”. External knowledge shows the greatest positive impact on the innovation performance of a firm only when it is combined with internal R&D activities. Rather surprisingly R&D co-operation does not show the expected significant positive effect.

Belderbos et al. (2004) analysed the impact of R&D co-operation on firm performance differentiating between four types of R&D partners (competitors, suppliers, customers as well as universities and research institutions), and considering two performance measures: labour productivity and productivity with respect to sales of innovative products. The data came from a sample of Dutch firms. Competitor and supplier co-operation focus on incremental innovations that improve labour productivity. University co-operation enhance particularly productivity with respect to sales of innovative products. Furthermore, customers and universities are important sources of knowledge for firms pursuing radical innovations that facilitate growth of sales innovative products in the absence of formal R&D co-operation.

Belderbos et al. (2006) assessed the performance effects of simultaneous engagement in R&D co-operation with different partners (competitors, clients, suppliers, and universities and research institutions). They tested whether these different types of R&D co-operation are complements in improving labour productivity. According to the results customer co-operation helps to increase market acceptance and diffusion of product innovation and enhances the impact of competitor and university co-operation. Smaller firms face diseconomies in pursuing multiple R&D co-operation strategies, which may stem from higher costs of simultaneously managing several partnerships. The study is based on data of Dutch firms from two surveys conducted in 1996 and 1998.

Lokshin et al. (2008) examined the impact of internal and external R&D on labour productivity in a 6-year panel of Dutch manufacturing firms and found complementarity between internal and external R&D, with a positive effect of external R&D evident only in case of sufficient internal R&D. Hagedoorn and Wang (2012) examined complementarity between internal and external R&D in pharmaceutical firms between 1986 and 2000. External R&D was based on R&D alliance or R&D acquisition. They found that complementarity depends on the level of internal R&D: at high levels internal and external R&D are complements, at low levels they are substitutes.

Grimpe and Hussinger (2008) investigated the complementarity effects of formal and informal technology transfer from Academia to Industry with respect to innovation performance. The analysis was based on a dataset of more than 2000 German firms. The results based on direct and indirect complementarity tests showed a complementarity relationship between informal and formal technology transfer.

In a further study based on data from the German part of the Community Innovation Survey (CIS3) Schmiedeberg (2008) provided evidence for significant complementarities between internal and R&D cooperation, but no complementarity between internal and R&D co-operation.

Focusing on industrial research laboratories in the USA, Adams and Marcu (2004) found that R&D sourcing is mainly driven by research joint ventures with federal government institutions. Sourcing saves R&D costs and secures access to technical services, but it does not affect innovation performance as measured by patents and new products. In contrast, internal research and research joint ventures increase innovation output.

With one exception (Cassiman and Veugelers 2006), all other reviewed studies investigated primarily complementarities between in-house R&D and external (contract) R&D but not between the external knowledge acquisition strategies (co-operation; external R&D), which is the main subject of this study. The findings vary not only by country of origin of the investigated corporates but also by the size of the firm samples that are used for the analysis, the target performance indicators and the reference period of the data. Most studies applied the direct method of testing complementarity, often based on the super-modularity condition for two activities (see Milgrom and Roberts 1990).

3. MODEL SPECIFICATION

Our interest here is not so much to re-address the complementarity between make and buy (Bönte, 2003; Cassiman and Veugelers, 2006; Hagedoorn and Wang, 2012; Lokshin et al., 2008), but rather to examine a possible complementarity between two external knowledge acquisition strategies: external R&D (BUY) and cooperation (COOP). External R&D corresponds to arm's length technology acquisition, i.e. through subcontracting and outsourcing. Collaboration refers to joint efforts, with risk-sharing, cost-sharing and knowledge-sharing. Hence the question is whether it pays to collaborate in addition to outsourcing or to outsource in addition to collaborating. We limit ourselves to firms that do internal R&D, as the question is not very relevant for firms that have no internal R&D activity at all.

In the Swiss innovation survey questionnaire there is no overlap between external R&D and cooperation, the former being essentially composed of R&D contracts, the latter excluding those contracts, and cooperation is restricted to R&D. In the Dutch CIS survey, external R&D does not exclude collaborative R&D, and cooperation pertains to the whole spectrum of innovation activities, not just to R&D. By concentrating on firms that do internal R&D, we minimize this difference in the definition of cooperation between the two countries.

We shall assess the existence and the extent of complementarity using the productivity approach and not the correlation approach, respectively PROD and CORR as Athey and Stern (1998) called them. The correlation approach verifies whether two strategies are adopted jointly after controlling for some other common determinants, the productivity approach tests whether the use of both strategies leads to a higher level of economic performance. It seems to us that the latter approach is more powerful as it tests directly the efficiency of using both strategies whereas the former tests only whether they are adopted jointly for reasons that cannot otherwise be explained. We shall first test whether doing both external R&D and collaborating leads to higher economic performance, i.e. we use only qualitative information on BUY and COOP and test complementarity using the notion of supermodularity (Milgrom and Roberts, 1990). Because of the potential overlap between external R&D and cooperation in the Dutch data, we then also analyse the complementarity on the basis of quantitative data, namely the amount of external R&D expenditure (as a share of sales) and the number of cooperation partners. Complementarity between two strategies then means that the marginal return of one strategy increases with the amount of the other strategy, where the return is defined in terms of some kind of payoff function. We have chosen as the payoff function the amount of product innovation, which is defined as the share in total sales due to new-to-the-firm or essentially improved products (in short, the share of innovative sales). To capture the complementarity effect, we include an interaction term of external R&D and number of cooperation partners.

We log-transform the share of innovative sales (y_{it}) and make it depend in a linear fashion on the external knowledge acquisition strategies (x_{it}^1) while controlling for other determinants of innovation output (x_{it}^2). Formally, we have

$$(1)\quad \ln y_{it} = \alpha + \beta_1 x_{it}^1 + \beta_2 x_{it}^2 + u_i + \varepsilon_{it}$$

where the error term has two independent components, one firm-specific, u_i, that is assumed to be normally distributed with mean 0 and variance σ_u^2, and one idiosyncratic, ε_{it}, that is assumed to be normally distributed with mean 0 and variance σ_ε^2. By allowing for an individual effect that is generated by a certain distribution (the random effect specification in panel data), we control for unobserved individual-specific determinants, which might affect the parameter estimates. The individual random effect is not correlated with the exogenous control variables (x_{it}^2), but might be correlated with the strategy variables (x_{it}^1). Therefore we resort to an instrumental variables estimator, where we project the dependent variable and the explanatory variables on the exogenous variables of the model and a set of excluded instruments, i.e. not appearing in (1) as explanatory variables. We have decided to control for individual heterogeneity through a random effect rather than a fixed effect for three reasons: it allows us to keep enterprises with only one observation, it keeps time-invariant variables, and it does not suffer from the incidental parameters problem.

For the reasons indicated above, we run (1) only on firms with R&D. Since not all innovators are internal R&D performers, it is necessary to correct for this selection bias. To this end, we follow the Heckman two-step procedure, i.e. we first run a probit (on the logarithmic transformations of firm size and the age of the firm, the obstacle "innovation costs", and foreign-owned firms as well as industry and time dummies for Switzerland, and on firm size, age and locational dummies according to the Dutch provinces, as well as industry and time dummies for the Netherlands) to select the firms that perform internal R&D and derive from it an inverse Mill's ratio (IMR), which we then introduce in equation (1) besides x_{it}^1 and x_{it}^2.

Whereas with the qualitative variables for BUY and COOP, internal R&D (MAKE) serves as the reference category, in the version with quantitative variables we must also control for the amount of internal R&D. Indeed, we can no longer ignore the fact that doing more internal R&D may also influence the share of innovative sales. Actually ignoring the possible effect of internal R&D may constitute a serious variable omission bias. Moreover, if we assume that firms maximize their performance by choosing their strategies appropriately, hence maximize w/t internal R&D, external R&D and number of cooperating partners, then, by the second-order conditions, the Hessian should be negative definite. If we exclude the own squared terms and only include the interaction terms, then the second principal minor will always have the wrong sign. Therefore, it is important to include the own squared terms in addition to the interaction terms.

Some firms may have no external R&D or no cooperation partners. To avoid having zeros, we increase all values of external R&D and number of cooperation partners by one (one thousand actually in the case of external R&D whose units are in thousands). These small changes should only slightly affect their marginal effects that will later be calculated.

We estimate (1) separately for the Dutch and Swiss firms, since in any case we are not allowed for reasons of statistical confidentiality to merge and share the data, but also because the coefficients in (1) might not be the same in the two countries and because the available variables that we want to control for are sometimes measured differently in the two countries.

4. DATA

In Switzerland and in the Netherlands innovation surveys have been conducted for a number of years so that panel data can be used to control for individual effects that might plague the conclusions regarding complementarity between cooperation strategies (Miravete and Pernías, 2006). For Switzerland we rely on the waves pertaining to the years 1997-1999, 2000-2002 and 2003-2005 (where the level observations, like the share of innovative sales, pertain to the years 1998, 2001 and 2004), and for the Netherlands on the waves pertaining to the years 1998-2000, 2000-2002 and 2002-2004 (where the level observations pertain to the years 2000, 2002 and 2004). From the three waves we construct an unbalanced panel of enterprises in manufacturing and in services.

INSERT TABLE 1

In table 1 we present the definitions and abbreviations of the variables that we shall use in our econometric analysis. Internal R&D, external R&D and sales of new products are normalized by total sales. Cooperation is measured by the number of cooperation partners. As already indicated in the previous section, we try to control for the same variables in the two countries, but some of them are measured differently, in particular regarding the number of cooperation partners and incoming knowledge spillovers. Moreover for the Netherlands we do not have a good measure for competition, the evolution of demand and technological potential.

INSERT TABLE 2

In table 2 we compare the frequencies of technology acquisition strategies for internal R&D performers between Switzerland and the Netherlands, in manufacturing and in services. The column sums of table 2 add up to 100%. In manufacturing, the proportion of firms that rely only on internal R&D is 33% higher in Switzerland than in the Netherlands, the proportions of firms that rely on internal R&D and external R&D or on internal R&D and R&D cooperation is pretty similar in the two countries, and the proportion of firms that use all three sources of knowledge acquisition is 24% in Switzerland compared to 30% in the Netherlands. In services, the difference is more pronounced: in Switzerland more than twice as many firms rely on internal R&D only, almost twice as many rely on internal R&D plus cooperation and one third of them rely less on internal R&D combined with either external R&D or with external R&D and cooperation, compared to the Dutch firms. Thus, in general the observed frequencies reveal that the Dutch firms favour open innovation more than the Swiss firms. The fact that a higher proportion of Dutch firms practice all three types of knowledge acquisition could in part be due to a less clearer definitional separation of external R&D and cooperation.

INSERT TABLE 3

In table 3 we present some descriptive statistics about the quantitative variables introduced in the analysis and the instrumental variables, again separately for manufacturing and for services. We notice that the average share of innovative sales is slightly higher in Switzerland (36% versus 31% in manufacturing and 27% versus 23% in services). In accordance with table 2, the intensity of internal R&D is substantially higher in Switzerland than in the Netherlands and in both countries higher in services than in manufacturing. In contrast, the intensity of external R&D is substantially higher in the Netherlands compared to Switzerland. Dutch firms spend on average three times as much as Swiss firms on external R&D in manufacturing and four times as much in services. The number of partnerships is about the same in the two countries if we normalize them by the maximum number of possible partnerships, which is almost twice as high in the Netherlands as in Switzerland. In the Dutch sample there are about twice as many MNEs as in Switzerland in manufacturing and three times as many in services, which could in part explain the difference in the amount of external R&D (R&D performed by a subsidiary of the MNE is internal to the MNE, but here it is considered as external to the firm). The average Dutch firm is younger and slightly larger than the average Swiss firm, both in manufacturing and in services. The choice of excluded instruments used to correct for the endogeneity of technology acquisition strategies is country specific.

5. RESULTS

In Tables 4 and 5 we report the estimation results for the specification with qualitative variables for technology acquisitions, for manufacturing and services respectively. We present two sets of estimates: in column I the estimates where the strategies are considered as exogenous, in column II those where instrumental variables are used because the strategies are considered as endogenous. We also control for time and industry dummies but do not report the corresponding coefficients. For column II, we use the following excluded instruments: *Educ*, *Hamp*, *Spil*, *Gp*, and province dummies for the Netherlands, and *Demand*, *Hper*, *Tp*, *IPC*, and *Spil1* for Switzerland.[1] The instruments pass various tests of weakness: the Hansen test does not reject the hypothesis of overidentification restrictions, the Kleinberg-Paap test of the null hypothesis of underidentification is rejected everywhere, except for services in the Netherlands.[2] In addition, the p-values of the F-statistics of the first-stage regressions are close to zero.

INSERT TABLE 4

INSERT TABLE 5

Since the strategies are measured as exclusive dummies (as in Table 2), with doing internal R&D only is the reference category, the test of complementarity consists in checking where the coefficient of the dummy indicating the use of all three strategies (internal, external and cooperative R&D) is larger than the sum of the coefficients of internal, external R&D & internal R&D and cooperation combination strategies. Although the interaction term is always significant (and often the only significant coefficient) in both countries we cannot reject the null hypothesis of no difference between the coefficients in line 3 and the sum of the coefficients in line 1 and 2. The reported p-values of the null hypothesis of no complementarity are all larger than 0.05. Instrumenting the knowledge acquisition strategies yields less precise estimators and does not lead to significantly different results.

[1] *Hamp* is the sum of the scores on the bottlenecks (*Hcos, Hper, Hfin* and *Hdem*) reported in Table 1. The mean of this variable is 3.09 (sd. 2.90) in the services sub-sample and 2.38 (sd 2.80) in the manufacturing sub-sample.

[2] We estimated the IV models without individual effects and then with the individual effects – the former allowing us to do the tests regarding the quality of the instruments, the latter giving us estimates of the individual effects.

The intensity of product innovation is not significantly related to the size of the firm, and if it is, it is negatively related to size. This is a classic result, which can easily be explained by the fact that innovative sales increase with additional innovation input but less than the total sales of the firm. Younger enterprises are more innovative (cf. Schneider and Veugelers, 2010) while foreign MNEs in our samples are not necessarily different from domestic firms when it comes to innovation intensity (cf. Belderbos et al, 2004; Dachs et al., 2008). The idiosyncratic component of the error term has a higher variance than the individual component. The insignificant inverse Mills ratio indicates that there is no systematic selection bias in examining only product innovators among the innovating firms.

INSERT TABLE 6

In Table 6 we tabulate the estimation results of an error component model with individual random effects, where quantitative measures of the three sources of technology acquisition are introduced in linear, squared and interaction terms, and, as before, size, MNEs, age, the inverse Mills ratio, time and province dummies are controlled for. The control variables have the same effects as in the specification with qualitative variables of technology acquisition. We shall concentrate on the seven coefficients pertaining to the technology acquisition variables. Although we recognize that these variables may be endogenous, we have too few good instruments to control for the endogeneity of those seven corresponding variables. Moreover, the results of Tables 4 and Table 5 seem to indicate that the results of IV regressions do not depart too much from those obtained without instrumenting. When we tried to estimate by IV using our small number of poor instruments, nothing became significant.

Overall, the results suggest that there are diseconomies of scale in both internal R&D and in external technology acquisition with the square terms of both R&D terms negative and significant in the Dutch data while in the Swiss sample the square terms on external technology acquisition terms are insignificant. The square term of the cooperation variable is not statistically significant in the Dutch sample, while it is positive and significant for Swiss manufacturing firms. Most of the interactions effects are not statistically significant. Conditional on performing internal R&D, the complementarity between Buy and Coop is given by the sum of the coefficients of the interaction terms of Buy&Coop and Buy&Make&Coop. This sum is positive in all cases suggesting at least that there are positive economies of scope in doing external and cooperative R&D together. However, we can conclude on the basis of these data and this model to the existence of complementarity between the two sources of open innovation only in the case of manufacturing in the Netherlands.

6. CONCLUSIONS

Whereas prior studies have either examined the complementarity of ‘make’ and ‘buy’, or the complementarity in different types of R&D collaboration, this study examines the complementarity between ‘buy’ and ‘cooperate’ in the presence of internal R&D. We compare the performance of firms that are only engaged in external technology sourcing, or only in cooperative R&D (with suppliers, customers, competitors and research institutions) and those that combine those two open innovation strategies. Using panel data on a large set of Swiss and Dutch innovating firms, we examine whether the two open innovation strategies are complementary in fostering firm innovation.

Informed by the growing literature on open innovation, we expected that the more firms rely on different external knowledge sourcing modes, the better they would perform in terms of innovation. While we find some evidence that both external technology sourcing and R&D

cooperation positively impact innovation in isolation, we hardly find evidence of an additional gain in performance when both are used simultaneously.

There are a number of possible ways to improve the specification, which we leave for future research. First, our measure of cooperation is rather crude, as we aggregate different types of partners (vertical, competitors, universities and research institutes) into one measure. There is some initial evidence that collaborative R&D projects between competitors are different from collaborative projects with other types of partners, as they are broader in scope and require less complementary, simultaneous research and development efforts from other external sources (Belderbos et al. 2012). This is one possible explanation for our difficulty in finding complementarity between 'buy' and 'cooperation' strategies. Another possibility is to also check for complementarity in terms of other objective functions. One payoff function could be innovation in general, including all dimensions of innovation (such as process innovation, unsuccessful or uncompleted innovations). The problem here is that we have no observations on R&D for non-innovators. Another performance criterion could be process innovation instead of product innovation, but then we could only use qualitative variables. A more economic performance criterion would be labour productivity, but in addition to data on capital stock, we might want to allow for some lag between the time choices are made about the way of acquiring technological knowledge and the time knowledge shows up in productivity figures, hence we would require one or two more waves of innovation surveys.

Table 1. Construction of variables

Variable name	Definition
	Dependent variable
New sales (*Newsales*)	Share in total sales of new (or essentially modified)-to-firm products , in %
	Independent variables
Make (*Make*)	Total intra-mural R&D expenditures, in 1000 Euros for the Netherlands, CHF for Switzerland, divided by sales, in %
Buy (*Buy*)	Total external R&D expenditures, in 1000 Euros for the Netherlands, CHF for Switzerland, divided by sales, in %
Cooperation (*Coop*)	A count of number of technology partnerships a firm reported engagement in (both domestically and internationally) with customers, suppliers, competitors, universities, research institutes, commercial labs, consultants, other enterprises within a group. For Switzerland the maximum number of technology partners is 13, in the Netherlands it is 25.
MNE (*MNE*)	1 if the headquarters of the firm are located outside the Netherlands/Switzerland, else 0
Age (*Age*)	Logarithm of number of years a firm exists
Firm size (*Size*)	Logarithm of number of employees
	(Excluded) Instruments
Incoming knowledge flows from industry & non-industry partners and incoming knowledge flows from public sources; for the Netherlands (*Spil*) for Switzerland (*Spil1*)	NL: Sum of scores of importance of information received from customers, suppliers, competitors for firm's innovative activities divided by the sum of scores of importance of information received from patents, conferences, and publications competitors for firm's innovative activities CH: Firms were asked to assess the importance of information received from competitors (Spil1) on a 5-point Likert scale
R&D researchers (*Educ*)	NL: Share of researchers and research assistants in total R&D employees
Part of a group (*Gp*)	NL: 1 if the enterprise is part of a larger group
Organizational constraints related to costs (*Hcos*)	NL: Firms were asked to assess the importance of innovation costs as a hampering factor to innovation (3-point Likert scale)
Organizational constraints related to organization rigidities (*Hper*)	NL: Firms were asked to assess the importance of lack of qualified staff as a hampering factor to innovation (3-point Likert scale). CH: Firms were asked to assess the importance of lack of R&D staff as a hampering factor to innovation (5-point Likert scale)
Organizational constraints related to finance (*Hfin*)	NL: Firms were asked to assess the importance of financing as a hampering factor to innovation (3-point Likert scale)
Organizational constraints related to technology (*Htec*)	NL: Firms were asked to assess the importance of lack of information on technology as a hampering factor to innovation (3-point Likert scale)
Organizational constraints related to demand (*Hdem*)	NL: Firms were asked to assess the importance of lack of information on markets/demand as a hampering factor to innovation (3-point Likert scale)
Demand development (*Demand*)	CH: Development of the demand during the last three years (5-point Likert scale)
Price competition *(IPC)*	CH: Firms were asked to assess the importance of price competition in their main product market (5-point Likert scale)
Technological potential (*Tp*)	CH: Assessment of the technological potential of the firm's main business activity (5-point Likert scale)

Table 2. Frequency (in percentages) of technology acquisition strategies among internal R&D performers

	Switzerland		Netherlands	
	Manufact.	Services	Manufact.	Services
No external R&D and no cooperation	36.14	41.70	27.47	19.86
External R&D only	29.90	27.20	32.81	43.04
Cooperation only	9.95	11.81	9.31	6.72
External R&D and cooperation	24.01	19.28	30.42	30.38

Table 3. Descriptive statistics

Variable name	Switzerland				Netherlands			
	Manufacturing		Services		Manufacturing		Services	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Newsales	36.17	26.31	26.90	25.16	31.24	24.73	23.40	23.56
Make	3.27	4.83	3.87	10.38	2.43	5.44	3.31	8.52
Buy	0.37	1.07	0.46	2.35	1.11	3.56	1.60	4.68
Coop	1.49	2.57	1.06	2.04	1.81	3.13	1.57	2.86
MNE	0.17	0.38	0.13	0.34	0.39	0.48	0.49	0.50
Age	3.81	0.86	3.62	0.94	3.01	0.71	2.67	0.82
Size	4.43	1.37	4.29	1.72	4.47	1.35	4.45	1.60
Spil/Spil1 (for CH)	2.80	1.12	3.08	1.12	0.32	0.42	0.35	0.47
Educ	-	-	-	-	0.53	0.24	0.44	0.29
Gp	-	-	-	-	0.50	0.50	0.48	0.50
Hcos	-	-	-	-	0.71	0.99	1.06	1.02
Hper	-	-	2.20	1.22	0.78	0.95	1.15	1.05
Hfin	-	-	-	-	0.72	0.98	1.04	1.08
Htec	-	-	-	-	0.54	0.77	0.73	0.88
Hdem	-	-	-	-	0.68	0.95	1.07	1.05
Demand	3.16	1.06	-	-	-	-	-	-
IPC	3.99	0.97	3.88	1.05	-	-	-	-
Tp	3.10	1.06	2.94	1.19	-	-	-	-

Table 4. Random-effects estimation of innovation performance with qualitative indicators of knowledge acquisition, Manufacturing

	Switzerland		The Netherlands	
Model	I	II	I	II
	Dependent variable: *Newsales*			
Buy only dummy	0.06 (0.06)	0.40 (1.29)	0.17*** (0.04)	0.23 (0.35)
Coop only dummy	0.03 (0.08)	-3.91 (3.06)	0.20*** (0.06)	0.51 (0.73)
Buy and Coop dummy	0.14** (0.06)	2.57*** (0.82)	0.26*** (0.05)	0.77*** (0.23)
Log Size	0.00 (0.02)	-0.16 (0.06)	-0.02 (0.02)	-0.07** (0.03)
MNE	0.02 (0.07)	0.02 (0.14)	0.01 (0.04)	0.01 (0.04)
Log Age	-0.11*** (0.03)	-0.06 (0.07)	-0.08 (0.03)	-0.06** (0.02)
IMR	0.00 (0.00)	-0.00 (0.01)	0.45 (0.43)	0.39 (0.41)
Intercept	3.26*** (0.16)	3.74*** (0.58)	2.86*** (0.40)	2.81*** (0.39)
σ_u	0.56	0.88	0.55	0.46
σ_e	0.83	1.66	0.79	0.86
Complementarity test (p-value)	0.26 (0.61)	-1.97 (0.16)	-0.11 (0.15)	0.03 (0.97)
No of firms	1419	1419	2486	2486
No of observations	2070	2070	3353	3353

*** Indicates significance at 1%, ** at 5%, * at 10% level, two-sided test. Standard errors are in parentheses. Omitted category is doing internal R&D only (no external R&D, no cooperation). All models include year dummies and industry dummies (23 for the Netherlands and 17 for Switzerland). The following (excluded) instruments are used in model II for the Netherlands: Educ, Hamp, Spil, Gp, and province dummies. The following (excluded) instruments are used in model II for Switzerland: Demand, Tp, IPC, and Spil1. The null hypothesis for the complementarity test is that the coefficient of the Coop & Buy dummy (doing internal and external R&D and cooperating) is equal to the sum of the coefficients of the Buy only (doing internal and external R&D) and Coop only (doing internal R&D and cooperating) dummies.
Model I: The dummies for Buy, Coop and Coop & Buy are not instrumented.
Model II: The dummies for Buy, Coop and Coop & Buy are instrumented

Table 5. Random-effects estimation of innovation performance with qualitative indicators of knowledge acquisition, Services

	Switzerland		The Netherlands	
Model	I	II	I	II
	Dependent variable: *Newsales*			
Buy only dummy	0.05 (0.11)	-1.27 (1.37)	0.18*** (0.07)	0.45 (0.92)
Coop only dummy	0.14 (0.14)	2.31 (1.90)	0.21* (0.12)	1.17 (1.38)
Buy and Coop dummy	0.16 (0.12)	1.59 (1.14)	0.16** (0.07)	0.73* (0.44)
Log Size	-0.02 (0.03)	0.01 (0.06)	-0.14*** (0.02)	-0.19*** (0.02)
MNE	0.11 (0.13)	0.09 (0.19)	0.02 (0.05)	0.02 (0.06)
Log Age	-0.12** (0.05)	-0.11 (0.08)	-0.07* (0.04)	-0.06 (0.04)
IMR	0.18 (0.13)	0.26 (0.20)	-0.09 (0.47)	-0.12 (0.54)
Intercept	2.64*** (0.25)	2.32*** (0.57)	3.12*** (0.32)	3.50*** (0.61)
σ_u	0.32	0.41	0.45	0.38
σ_e	1.05	1.37	0.90	0.99
Complementarity test	0.02 (0.88)	0.04 (0.83)	-0.23* (0.09)	-0.88 (0.65)
No of firms	527	527	1549	1549
No of observations	669	669	1682	1682

*** Indicates significance at 1%, ** at 5%, * at 10% level, two-sided test. Standard errors are in parentheses. Make Only (no Buy, no Coop). All models include year dummies and industry dummies (4 in the Netherlands and 8 in Switzerland). The following (excluded) instruments are used in model II for the Netherlands: Educ, Hamp, Spil, Gp, and province dummies. The following (excluded) instruments are used in model II for Switzerland: Tp, Hper, IPC, and Spil1. The null hypothesis for the complementarity test is that the coefficient of the Coop & Buy dummy (doing internal and external R&D and cooperating) is equal to the sum of the coefficients of the Buy only (doing internal and external R&D) and Coop only (doing internal R&D and cooperating) dummies.

Model I: The dummies for Buy, Coop and Coop & Buy are not instrumented.

Model II: The dummies for Buy, Coop and Coop & Buy are instrumented

Table 6. Random-effects estimation of innovation performance with quantitative indicators of knowledge acquisition

	Switzerland		The Netherlands	
	Manufacturing	Services	Manufacturing	Services
	Dependent variable: *Newsales*			
Make: internal R&D intensity	3.99*** (1.23)	3.48** (1.43)	6.89*** (0.69)	5.10*** (0.78)
Internal R&D intensity Squared	-8.40** (4.27)	-3.77** (1.92)	-11.21*** (2.51)	-5.14*** (1.24)
Buy: external R&D intensity	4.15 (5.90)	6.10 (5.82)	3.79*** (0.88)	4.34*** (1.16)
External R&D intensity Squared	-51.49 (72.14)	-4.26 (26.96)	-7.38** (3.11)	-4.20** (1.68)
Coop: no of cooperation partners	-0.17 (0.12)	0.24 (0.23)	0.04*** (0.01)	0.01 (0.01)
Coop Squared	0.13** (0.06)	-0.11 (0.13)	-0.00 (0.00)	0.00 (0.00)
Buy & Make	-3.31 (34.70)	-9.94 (28.51)	-3.04 (5.49)	-14.06* (5.42)
Buy & Coop	-4.63 (4.87)	-1.18 (7.69)	-0.61*** (0.21)	-0.09 (0.20)
Coop & Make	0.13 (0.72)	-0.05 (0.86)	-0.06 (0.08)	-0.07 (0.14)
Buy & Make & Coop	20.72 (18.32)	12.58 (36.85)	1.78*** (0.54)	1.55 (1.37)
Log Size	0.01 (0.02)	-0.02 (0.04)	-0.01 (0.02)	-0.14*** (0.02)
MNE	0.03 (0.07)	0.04 (0.14)	0.01 (0.04)	0.04 (0.05)
Log Age	-0.09*** (0.03)	-0.10* (0.05)	-0.05* (0.02)	-0.05 (0.03)
IMR	-0.00 (0.00)	0.20 (0.13)	0.48 (0.37)	0.09 (0.46)
Intercept	3.17*** (0.16)	2.50*** (0.25)	2.61*** (0.38)	3.53*** (0.17)
σ_u	0.56	0.31	0.52	0.35
σ_e	0.85	1.04	0.79	0.92
No of firms	1390	502	2486	1549
No of observations	2004	637	3353	1682

*** Indicates significance at 1%, ** at 5%, * at 10% level, two-sided test. Robust standard errors are in parentheses. Random effects maximum likelihood estimator. The models for the Netherlands include 23 industry dummies (manufacturing subsample) and 4 service dummies (services subsample). The models for Switzerland include 17 industry dummies (manufacturing subsample) and 8 industry dummies (services subsample).

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